Citation:

Godwin SL, Fur-Chi C, Coppings RJ. Correlation of visual perceptions of cleanliness and reported cleaning practices with measures of microbial contamination in home refrigerators. *Food Protection Trends*. 2006; 26 (7): 474-480.

Study Design:

Cross-sectional study

Class:

D - Click here for explanation of classification scheme.

Research Design and Implementation Rating:

 NEUTRAL: See Research Design and Implementation Criteria Checklist below.

Research Purpose:

- To collect information from consumers regarding their food handling and refrigeration knowledge and practices
- To visually assess the contents and cleanliness of home refrigerators
- To evaluate microbial contamination on surfaces within consumers' refrigerators by use of the microbial ATP (mATP) bioluminescence assay.

Inclusion Criteria:

- Included in a follow-up of a previous consumer study on food handling and refrigeration knowledge and practices study
- Living in Florida or Tennessee.

Exclusion Criteria:

- Not in previous consumer study on food handling and refrigeration knowledge and practices study
- Not living in Florida or Tennessee.

Description of Study Protocol:

Recruitment

Researchers used an earlier comprehensive consumer study on food handling and refrigeration knowledge and practices study to draw participants for a follow up in-home study of subjects living in Florida or Tennessee.

Design

- Participants completed a home refrigeration practices survey
- Conditions of the participants' refrigerators were evaluated by a trained observer
- Cleanliness, fullness and organization of five areas (door, upper, middle shelves, bottom

shelves and vegetable bins) of each refrigerator were recorded on a four-point scale and potentially unsafe circumstances were noted
- Several 100cm^2 areas of each refrigerator (usually meat area (either a compartment or location where meat was stored), bottom shelf and vegetable bin) were swabbed with sterile buffer
- An mATP bioluminescence assay was performed on the swabs to assess microbial contamination.

Dietary Intake/Dietary Assessment Methodology

Not applicable.

Blinding Used

Not applicable.

Intervention

Not applicable.

Statistical Analysis

- Survey responses and checklists results were numerically coded if possible and entered into SPAA-PC
- For certain analyses, RLU Results, reflecting mATP, were recoded into five categories (equivalence to CFU per 100cm^2):
  - Non-detectable (less than 10^3)
  - Up to 2,000 (10^3 to 10^5)
  - 2,001 to 20,000 (10^5 to 10^6)
  - 20,001 to 200,000 (10^6 to 10^7)
  - Over 200,000 (greater than 10^7)
- Also used to evaluate the data:
  - Frequency analysis
  - Pearson correlation
  - Chi-Square
  - One-way Analysis of Variance
  - Tukey's Multiple Comparison tests.

Data Collection Summary:

Timing of Measurements

- A minimum of two surfaces were swabbed in each refrigerator
- Timing of measurements in all refrigerators not specified.

Dependent Variables

Microbial ATP levels in sampled areas (measured via bioluminesence assay performed by use of a microluminometer NHD Model 3560) and PROFILE®-1 Reagent Kit (New Horizons Diagnostic).

Independent Variables

- Self-reported refrigerator practices including:
  - Handling of cold foods

- Cleaning frequency
- Recorded condition of consumer's refrigerator with respect to cleanliness, fullness and organization (based on scoring by trained observer using a checklist)
  - In the case of cleanliness, observers used scoring system in which 1=very clean and 4=dirty
- Also recorded circumstances that might allow for cross-contamination of foods, presence of moldy or spoiled food or unsealed containers and other potentially unsafe or unusual conditions within the refrigerator.

Control Variables

None.

Description of Actual Data Sample:

- *Initial N:* 147 subjects and household refrigerators in Florida or Tennessee
- *Attrition (final N):*
  - 147 subjects (84% female, 16% male);
  - 147 household refrigerators (minimum of two surfaces swabbed in each refrigerator; total number of samples=369)
- *Age:* For members of households: 31% contained at least one elderly individual; 36% had children; 10% had a toddler or infant
- *Ethnicity:*
  - 53% White, non-Hispanic
  - 31% African American
  - 14% Hispanic
- *Other relevant demographics:*
  - 92% of participants had high school diplomas or degrees
  - 84% had a household income of more than $15,000
  - 12% of households consisted of five or more persons
- *Anthropometrics:* Not applicable
- *Location:* Florida or Tennessee, US.

Summary of Results:

Key Findings

- Refrigerator observations:
  - About 78% of refrigerator areas were scored as either very clean or clean, 20% were judged slightly dirty and only 2% were considered dirty
  - Refrigerator doors were judged slightly cleaner than the bottom shelves and vegetable bins
  - Cleanliness scores for each of the five refrigerator areas were correlated with one another in all cases.
- Microbial ATP:
  - Although the highest RLU (relative luminescence units) were observed in the meat storage area and the vegetable bin, variation within each refrigerator location was large
  - Overall, 72% of swabs had detectable mATP, suggesting that the majority of home refrigerators contain viable microbial populations

- Vegetable bins had fewer non-detectable (14%) and more elevated mATP outcomes (greater than 15%) than other areas swabbed
- Although meat areas in a number of refrigerators showed elevated mATP, the greatest percentage of samples with non-detectable levels were also in this area.

- Cleanliness score and mATP
  - Microbial ATP on the bottom shelf correlated with the cleanliness score for that area ($r=0.210$, $P<0.05$)
  - Cleanliness scores for all the refrigerator compartments except the vegetable bins were correlated ($r=0.167$ to 0.236, $P<0.05$), with mATP found on the bottom shelf suggesting that bacteria settle from upper shelves to bottom shelf.
- Reported cleaning practices and mATP
  - About three-quarters of participants frequently cleaned up spills in their refrigerators
  - Refrigerators of consumers who more often clean spills in their refrigerators had greater mATP values on the bottom shelves ($r=0.251$, $P<0.05$)
  - A majority of participants often or occasionally cleaned compartments within their refrigerators, but half rarely or never empty and clean the refrigerator
  - Mean mATP was greater in refrigerators that were emptied and cleaned less frequently
  - Microbial ATP was inexplicably low in the vegetable bins of those who never thoroughly cleaned their refrigerators
  - Data from other compartments failed to show a clear relationship between refrigerator cleaning frequency and mATP
  - Microbial ATP in the vegetable bin was correlated with the cleanliness score for that compartment ($r=0.252$, $P<0.01$), but mATP was not related to the self-reported frequency of washing the vegetable bins.

Table: Percent of Sampled Locations in Refrigerators by mATP Concentration

ATP Concentration (Relative Luminescence Units-RLU)					
Locations in Refrigerator	**Non-detectable**	**Up to 2,000**	**2k-200k**	**20k-200k**	**Over 200k**
Top shelf	25.0	70.0	5.0	--	--
Middle shelf	19.2	73.1	7.7	--	--
Meat area	40.2	47.1	8.0	3.4	1.1
Bottom shelf	31.0	62.8	4.1	2.1	--
Vegetable bin	14.0	59.4	--	--	--

Author Conclusion:

- A majority of swabbed surfaces of consumer refrigerators contain detectable populations of bacteria as assessed by ATP bioluminescence, indicating the presence of viable microbial populations in most home refrigerators
- Refrigerator cleanliness scores and mATP results support the hypothesis that contaminants within a home refrigerator may settle to the bottom shelf
- Vegetable bins of home refrigerators commonly showed the highest mATP levels, perhaps due to the storage practices of consumers
- Visual appraisal is not a reliable method of assessing microbial contamination within a home refrigerator, nor are self-reported cleaning practices of consumers reliable in predicting

microbial contamination.

Reviewer Comments:

- *Subjectivity of trained observers' cleanliness scores (lack of validity of scoring tool)*
- *The authors noted these limitations:*
  - *ATP bioluminescence results may be altered by the presence of cleaning agents and chemical sanitizers or disinfectants (and about two-thirds of subjects in this study reported using some type of cleaning compound either often or occasionally within their refrigerators)*
  - *Speculation that some participants may have cleaned their refrigerators before the researchers arrived, even though they had been asked not to do so (This cleaning was apparent to the researchers in a few instances)*
  - *Visual assessment of cleanliness may not be a reliable indicator of microbial contamination.*

Research Design and Implementation Criteria Checklist: Primary Research

Relevance Questions

1.	Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (Not Applicable for some epidemiological studies)	Yes
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes
3.	Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to nutrition or dietetics practice?	Yes
4.	Is the intervention or procedure feasible? (NA for some epidemiological studies)	Yes

Validity Questions

1.	**Was the research question clearly stated?**	Yes
1.1.	Was (were) the specific intervention(s) or procedure(s) [independent variable(s)] identified?	Yes
1.2.	Was (were) the outcome(s) [dependent variable(s)] clearly indicated?	Yes
1.3.	Were the target population and setting specified?	???
2.	**Was the selection of study subjects/patients free from bias?**	No

2.1.	Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	???
2.2.	Were criteria applied equally to all study groups?	???
2.3.	Were health, demographics, and other characteristics of subjects described?	No
2.4.	Were the subjects/patients a representative sample of the relevant population?	???
3.	**Were study groups comparable?**	???
3.1.	Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	N/A
3.2.	Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	N/A
3.3.	Were concurrent controls used? (Concurrent preferred over historical controls.)	N/A
3.4.	If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	???
3.5.	If case control or cross-sectional study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	???
3.6.	If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	N/A
4.	**Was method of handling withdrawals described?**	No
4.1.	Were follow-up methods described and the same for all groups?	No
4.2.	Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	No
4.3.	Were all enrolled subjects/patients (in the original sample) accounted for?	???
4.4.	Were reasons for withdrawals similar across groups?	???
4.5.	If diagnostic test, was decision to perform reference test not dependent on results of test under study?	N/A
5.	**Was blinding used to prevent introduction of bias?**	???

5.1.	In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	N/A
5.2.	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	N/A
5.3.	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	???
5.4.	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	N/A
5.5.	In diagnostic study, were test results blinded to patient history and other test results?	N/A
6.	**Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were interveningfactors described?**	N/A
6.1.	In RCT or other intervention trial, were protocols described for all regimens studied?	N/A
6.2.	In observational study, were interventions, study settings, and clinicians/provider described?	N/A
6.3.	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	N/A
6.4.	Was the amount of exposure and, if relevant, subject/patient compliance measured?	N/A
6.5.	Were co-interventions (e.g., ancillary treatments, other therapies) described?	N/A
6.6.	Were extra or unplanned treatments described?	N/A
6.7.	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	N/A
6.8.	In diagnostic study, were details of test administration and replication sufficient?	N/A
7.	**Were outcomes clearly defined and the measurements valid and reliable?**	No
7.1.	Were primary and secondary endpoints described and relevant to the question?	Yes
7.2.	Were nutrition measures appropriate to question and outcomes of concern?	Yes
7.3.	Was the period of follow-up long enough for important outcome(s) to occur?	N/A
7.4.	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	No
7.5.	Was the measurement of effect at an appropriate level of precision?	No
7.6.	Were other factors accounted for (measured) that could affect outcomes?	No

7.7.	Were the measurements conducted consistently across groups?	Yes
8.	**Was the statistical analysis appropriate for the study design and type of outcome indicators?**	Yes
8.1.	Were statistical analyses adequately described and the results reported appropriately?	Yes
8.2.	Were correct statistical tests used and assumptions of test not violated?	Yes
8.3.	Were statistics reported with levels of significance and/or confidence intervals?	Yes
8.4.	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	N/A
8.5.	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	No
8.6.	Was clinical significance as well as statistical significance reported?	Yes
8.7.	If negative findings, was a power calculation reported to address type 2 error?	N/A
9.	**Are conclusions supported by results with biases and limitations taken into consideration?**	N/A
9.1.	Is there a discussion of findings?	Yes
9.2.	Are biases and study limitations identified and discussed?	Yes
10.	**Is bias due to study's funding or sponsorship unlikely?**	Yes
10.1.	Were sources of funding and investigators' affiliations described?	Yes
10.2.	Was the study free from apparent conflict of interest?	Yes